BIOSTROMES IN THE NAMURIAN GREAT LIMESTONE OF NORTHERN ENGLAND

by G. A. L. JOHNSON

ABSTRACT. Recent research has shown that the base of the Great Limestone of northern England lies close to the junction between the Lower and Upper Carboniferous and this stratum has thus gained a new significance. The fauna and lithology of three biostromes, the *Chaetetes* Band, Brunton Band, and Frosterley Band, which occur persistently in the Great Limestone are described in detail. Two of these, the coralline *Chaetetes* Band and the algal Brunton Band are new; they are of widespread occurrence in northern England. The Frosterley Band (Dunham 1948) is mainly restricted to the Alston Block. A new fossil alga *Calcifolium bruntonense* sp. nov. is described and figured.

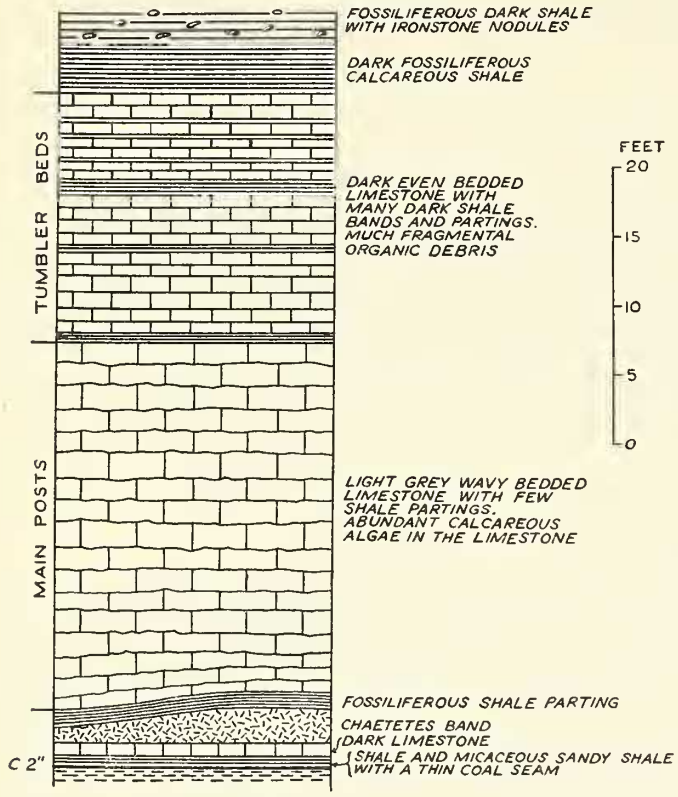
INTRODUCTION

THE presence of persistent biostromes in the Carboniferous Limestone of northern England was first described by Garwood (1913) whose '*Girvanella* Band' at the base of the D_2 Zone is perhaps the best known. Recently J. S. Turner (1956) has described faunal bands in the Yoredale Scar Limestone and Four Fathom Limestone of the Askrigg Block. The present paper concerns similar biostromes in the Yoredale Great Limestone which are particularly well developed on the Alston Block (northern Pennines). The bands consist of two coralline biostromes, one near the base and one near the centre of the limestone and an algal biostrome also near the centre of the limestone. The term biostrome means literally an organic layer and according to Cumings (1932, p. 334) they are by definition '. . . purely bedded structures, such as shell beds, crinoid beds, coral beds, etcetera, consisting and built mainly by sedentary organisms, and not swelling into moundlike or lenslike forms . . .'. The fossiliferous bands in the Great Limestone do lens to some extent but this is rarely perceptible and they are thus nearer true biostromes than bioherms; the former term is therefore retained in describing them.

The Great Limestone lies at the base of the Upper Limestone Group (Upper Bernician) of northern England and is a persistent and characteristic limestone member of a Yoredale type succession. To the south the Great (= Main) Limestone is known throughout the northern Pennines and northwards the Great (= Dryburn) Limestone has been traced to the Scottish Border (Gunn 1898; Trotter 1952; Rayner 1953). Throughout northern England the limestone lies at the top of a sequence of well-developed Yoredale cyclothems and underlies a rather different succession characterized by thick sandstones and grits with thin limestones; a faunal change also takes place in the vicinity of the Great Limestone. The lithological and faunal changes at this horizon led Stanley Smith (1910) to choose the base of the Great Limestone for the top of the D_2 Zone in Northumberland. Later Fowler (1926) adopted this horizon for the boundary between his Middle Limestone Group and Upper Limestone Group. This boundary has since been used satisfactorily in Northumberland, the Brampton district, Cumberland (Trotter and Hollingworth 1932), and the northern Pennines (Dunham 1948). The position of the Great Limestone in the Carboniferous zonal scheme has changed considerably since Smith's original work. The results of recent research are summarized by Rayner (1953)

[Palaeontology, Vol. 1, Part 2, 1958, pp. 147–157, pls. 30–31.]

who indicates that the Viséan–Namurian junction lies in the vicinity of the base of the Great Limestone. This boundary is a satisfactory junction between the Lower and Upper Carboniferous in northern England. Furthermore, it agrees with the Viséan–Namurian junction in Scotland where Currie (1954) has shown that it lies at the base of the Top Hosie Limestone on independent palaeontological evidence; the Top Hosie is equated with the Great Limestone with some certainty (Trotter 1952). The Great Limestone is now regarded as of basal E_1 age, Namurian.



TEXT-FIG. 1. Vertical section of the Great Limestone at Brunton Bank, Chollerford, near Hexham, Northumberland.

Acknowledgements. The writer wishes to acknowledge the assistance of Professor T. S. Westoll under whose guidance the initial research in Northumberland was conducted. He is indebted to Drs. H. Ll. L. Jones, A. J. Wells, and A. A. Wilson for supplying unpublished information on the biostromes, to Mr. J. S. Turner for demonstrating the presence of the biostromes in the upper Eden Valley area, and to Mr. G. F. Elliott and Dr. W. H. C. Ramsbottom for supplying the references to *Calcifolium*. Professor S. I. Tomkeieff greatly assisted in the translation of Russian literature and Professor K. C. Dunham has kindly checked the manuscript. Thanks are also due to the late Mr. G. W. O'Neill and to Mr. C. Chapman for help with the photography, and to Mr. A. Warne who prepared text-figs. 1 and 3 for publication.

FORM AND COMPOSITION OF THE GREAT LIMESTONE

The Great Limestone of the Alston Block and Northumberland Trough has an average thickness of about 50 feet and is the thickest of the Yoredale limestones. In general it is divisible into three parts (text-fig. 1): a lower dark-coloured limestone 2 or 3 feet thick, a central division of light-coloured limestone 25 to 30 feet thick, called the Main Posts, and an upper division of dark-coloured limestone with intercalated shales called the Tumbler Beds.

The lower division of the Great Limestone rests on either sandstone, shale, or a thin coal seam and there is often evidence of disconformity. The limestone is here even-bedded dark coloured and relatively unfossiliferous with few colonial corals and brachiopods. In micro-section the basal beds contain scattered angular quartz grains and argillaceous material with fairly abundant foraminifera and bryozoans. The argillaceous lower division of the Great Limestone is not of best quality for lime burning and is frequently left in place to form a hard quarry floor.

At the base of the central division of the Great Limestone lies the *Chaetetes* Band coralline biostrome. The band may be up to 3 feet thick and composed almost exclusively of tabular masses of *Chaetetes depressus* (Fleming); the limestone in the vicinity of the band is often dolomitic. Above the *Chaetetes* Band the Main Posts division of the lime-

stone consists of thick beds of light-coloured limestone having conspicuous undulating or wavy bedding. In micro-sections the Main Posts are seen to be composed of fine shell and crinoid debris with abundant foraminifera and calcareous algae and quantities of fine-grained calcitic matrix. Calcareous algae are particularly numerous in the central and upper part of the division where the micro-fossil *Calcifolium bruntonense* sp. nov. is abundant and forms the Brunton Band. Near the top of the Main Posts division of the Great Limestone of the Alston Block and above the Brunton Band lies the Frosterley Band coralline biostrome. This band is persistent over the Alston Block and some neighbouring areas and is characterized by abundant simple corals particularly *Dibunophyllum bipartitum* (M'Coy). It is usually composed of several coralline beds divided by beds normal limestone and thin marl partings.

The upper division of the Great Limestone, called the Tumbler Beds, is composed of bands of even-bedded fragmental limestone separated by partings and bands of dark calcareous shale. The proportion of shale to limestone is very variable in the Tumbler Beds and locally the shales may be absent. Further information on this and other characters of the Great Limestone of the northern Pennines is given in Dunham (1948).

THE *CHAETETES* BAND

At Brunton Bank Quarry, Chollerford, near Hexham, Northumberland (grid ref. 35/928570), the *Chaetetes* Band is in the form of a bed varying between 1 and 3 feet in thickness. It is almost completely composed of compound corals surrounded and cemented by small quantities of yellow weathering dolomitic matrix. The band lies 3 feet above the base of the limestone and is overlain by a richly fossiliferous dark shale parting (text-fig. 1). Elsewhere the thickness and form of the *Chaetetes* Band varies considerably though the coral *Chaetetes depressus* is almost everywhere present as is the dolomitic matrix. In some places where *Chaetetes* has not been found the presence of other compound corals, particularly *Lonsdaleia laticlavia* S. Smith, in a dolomitic matrix is diagnostic of the *Chaetetes* Band horizon. In upper Allendale, Northumberland, where the development of *Chaetetes* is patchy and areas devoid of coral colonies occur, the dolomitic matrix is persistent. Similarly in the Barnard Castle neighbourhood, south Durham, a dolomitic band occurs 3 feet above the base of the Great (= Main) Limestone in which *Chaetetes depressus* has been found; the coral is not abundant and the *Chaetetes* Band is poorly developed in this area.

The form of the *Chaetetes* Band varies considerably from place to place due to variations in the amount of coralline material and matrix. At Brunton Bank the band is almost completely composed of tabular coral colonies piled one on top of the other; a similar development can be seen in a cutting by the Alston to Penrith road, 3 miles from Alston, Cumberland. The *Chaetetes* Band in these areas is in the form of large lenses which can be seen to thin out laterally to a narrow band in some places. At Killhope, upper Weardale, *Chaetetes* is not so abundant in the *Chaetetes* Band and occurs as isolated colonies up to 1 foot in diameter on a single bedding-plane. The colonies are evenly scattered on the bedding-plane which is 2 feet above the base of the Great Limestone and occur with colonies of *Lonsdaleia laticlavia* and *Syringopora*. Occasionally, as in the upper Eden valley south of Kirkby Stephen, Westmorland, the coralline material of the *Chaetetes* Band is separated by bands of limestone and may reach a total thickness of 5 feet or more.

Fauna. The fauna of the *Chaetetes* Band has been examined at Brunton Bank where it is particularly well exposed. The band is here almost completely composed of compound corals among which *C. depressus* is overwhelmingly predominant. Simple rugose corals and brachiopods occur in the dolomitic matrix between the tabular *Chaetetes* colonies but are not abundant. Where the underside of the *Chaetetes* colonies is visible a fauna of adherent bryozoans, annelids, brachiopods, &c., is found. The brachiopods are particularly interesting and include a new genus and species of leptaenoid form the affinities of which have yet to be fully deciphered. The following species have been recorded from the *Chaetetes* Band at Brunton Bank, Chollerford, Northumberland:

Aulopora ?, *Caninia cornucopiae* Michelin, *Chaetetes depressus* (Fleming), *Chaetetes septosus* (Fleming), *Cladochonus brevicollis* (M'Coy), *Dibunophyllum bipartitum* (M'Coy), *Diphyphyllum lateseptatum* (M'Coy), *Koninckophyllum echinatum* (Thomson), *Lithostrotion pauciradiale* M'Coy, *Lonsdaleia laticlavia* S. Smith, *Syringopora geniculata* (Phillips).

Serpula sp., *Spirorbis* cf. *laxus* Hall.

Archaeocidaris urei (Fleming), crinoid columnals up to 12 mm. diameter.

Fenestella spp., *Polypora sp.*, *Stenopora sp.*, indet. stick bryozoans.

Actinoconchus planosulcatus (Phillips), *Athyris lamellosa* (Léveillé), *Brachythyris decora* (Phillips), *Crania quadrata* (M'Coy), *Dictyoclostus pugilis* (Phillips), *Echinoconchus punctatus* (Martin), *Eomarginifera longispina* (J. Sowerby), *Overtonia fimbriata* (J. de C. Sowerby), *Rhipidomella michelini* (Léveillé), *Schellwienella crenistria* (Phillips), *Sinuatella sinuata* (de Koninck), *Spirifer sp.*, *Tylothyris* cf. *subconica castletonensis* North.

Known distribution. The *Chaetetes* Band is well developed in western Northumberland where it was first recognized and is known northwards in the Alnwick district. In southwest Northumberland it occurs in the Allendale area and is well developed near Allenheads and underground in Swinhope Mine. It is present in Weardale and Teesdale on the Alston Block, and occurs on the Pennine escarpment (Cumberland and Westmorland Pennines) and underground here in Silverband Mine (Dunham 1948, gives full details of the northern Pennine mines). On the west of the Pennine escarpment it has been found at King's Meaburn, near Appleby, in the Great Strickland (= Great) Limestone and farther south the *Chaetetes* Band is well developed in the upper Eden Valley near Kirkby Stephen, Westmorland. At the north-east corner of the Askrigg Block the *Chaetetes* Band has been recorded by Wells (1958) in the Richmond area, and farther south it may be present in Wensleydale where Hudson (1924) recorded a coral band at this position, but the exact fauna was not given.

THE BRUNTON BAND

This band lies towards the centre and top of the Main Posts division of the Great Limestone and is a persistent algal biostrome characterized by abundant remains of *Calcifolium bruntonense* sp. nov.—an algal genus new to this country. Algal limestones have previously been recorded from this position in Yoredale limestones (Hudson 1924) but *Calcifolium* is almost restricted to the Great Limestone where it is a conspicuous member of the algal limestone fauna.

At Brunton Bank Quarry the Brunton Band lies about 18 feet above the base of the Great Limestone and is of the order of 12 feet thick. It is formed of light grey-coloured

limestone with occasional shaly partings and well-developed wavy-bedding, i.e. hummocky bedding-planes. The limestone is rather unfossiliferous except for the microfauna which is both varied and abundant; occasional brachiopods occur in the limestone. In micro-sections foraminifera and calcareous algae are conspicuous and invariably present with amounts of fine calcitic matrix. In Middle Tongue Beck, Great Dun Fell, Westmorland, the Brunton Band lies about 16 feet above the base of the Great Limestone and is some 19 feet thick; it lies directly below the Frosterley Band in this section. The position of the Brunton Band below the Frosterley Band appears to be general though occasional fragments of *Calcifolium*, perhaps derived fragments, have been found above the Frosterley Band.

The Main Posts division of the Great Limestone is very distinctive in the field but here the Brunton Band cannot be distinguished. In micro-sections, however, the presence of abundant *C. bruntonense* is easily recognizable (Pls. 30 and 31) and is diagnostic of the band. It is noteworthy that *C. bruntonense* is, as far as is known, almost restricted to the Main Posts of the Great Limestone. It has been found once in the underlying Four Fathom Limestone and once in the Five Yard Limestone at localities in western Northumberland. The abundance of *C. bruntonense* varies considerably through the thickness of the Brunton Band and also laterally from place to place. In general the organism is abundant in the central and upper parts of the band and sections from here may show the limestone to be packed with its remains.

Fauna and flora. The following species were recorded in micro-sections from the Brunton Band, Brunton Bank Quarry, Chollerford, Northumberland:

Calcifolium bruntonense sp. nov., Dasycladacian algae, *Girvanella sp. nov.* (tubules in contact laterally to form thin sheets).

Ammodiscids, Endothyrids, Nodosariids, Tetrataxiids, Textulariids.

Fragmental organic debris including: small rugose corals indet., *Archaeocidaris sp.* [radioles and plates], small crinoid columnals, indet. bryozoans, brachiopod and gastropod shells, ostracods.

Known distribution. The Brunton Band is well developed in western Northumberland, where the organism was first discovered, and has been traced as far northwards as the Morpeth district, central Northumberland. On the Alston Block it occurs below the Frosterley Band and is well developed in the Westmorland and Cumberland Pennines. The Brunton Band is present in the Barnard Castle area of south Durham and has been recorded by Dr. H. Ll. L. Jones in the Middleton in Teesdale district. Farther south on the eastern side of the Askrigg Block it has been found by Dr. A. J. Wells in the area north of Richmond and by Dr. A. A. Wilson in Coverdale, south-west of Leyburn, Yorkshire.

THE FROSTERLEY BAND

This is a persistent though lenticular coralline biostrome characterized by abundant remains of simple rugose corals particularly *Dibunophyllum bipartitum* (M'Coy). It lies normally about 24 feet below the top of the Great Limestone and varies between a foot and 3 feet in thickness except where it is divided by beds of limestone when it may be considerably thicker. At Harehope Quarry (grid ref. 45/037365), south-east of Frosterley in Weardale, where for many years stone from the band has been wrought for ornamental

purposes under the name Frosterley Marble, the band is divided by beds of limestone into several coralline horizons the general section of which is as follows:

Grey crinoidal limestone		
Frosterley Band	Coralline limestone with *Dibunophyllum*	6″
	Grey fragmental limestone	9″
	Coralline limestone with *Dibunophyllum*	3″
	Grey limestone with compound corals	2′ 0″
	Coralline limestone with *Dibunophyllum*	1′ 6″
	Grey fragmental limestone	6″
	Coralline limestone with *Dibunophyllum*	4″
	Grey fragmental limestone	2′ 0″
	Coralline limestone with *Dibunophyllum*	3″
	Grey fragmental limestone	1′ 3″
	Coralline limestone with *Dibunophyllum*	1′ 6″
Grey fragmental limestone		

A similar section occurs at Greenfield Quarry, one mile north-north-west of Cowshill in Weardale (grid ref. 35/852423). In other areas such as the Great Dun Fell district, Westmorland Pennines, the Frosterley Band occurs as a single stratum within the limestone. The discontinuous nature of the Frosterley Band is not a conspicuous feature and the individual lenses must be of considerable extent. The lenticular nature of the band is well seen in Greenfield Quarry, Cowshill, where a richly fossiliferous coralline bed 2 feet thick can at one point be seen to die out within 2 yards along the quarry face.

The fauna of the Frosterley Band is very distinctive, being composed of abundant simple rugose corals, mainly *Dibunophyllum*, *Koninckophyllum*, *Aulophyllum*, and *Caninia*, with some brachiopods and few compound rugose corals, usually *Lonsdaleia* and *Diphyphyllum*. The simple corals are frequently found in a rolled condition and partly devoid of epitheca, very few are found in position of growth, most lie almost horizontally in the limestone matrix and some are overturned. Some of the colonies of *Lonsdaleia* also occur overturned in the Frosterley Band and provide further evidence of strong current action during or shortly after deposition. It seems possible that the discontinuous nature of the Frosterley Band may in part be due to current scouring.

Fauna. Although compound rugose corals and brachiopods occur in the Frosterley Band they are everywhere relatively insignificant compared with an overwhelming predominance of simple corals particularly *Dibunophyllum bipartitum* (M'Coy); this species is of particular interest in the band owing to the high degree of variation which it shows (Johnson 1956). At Harehope Quarry, near Frosterley in Weardale, the Frosterley Band fauna includes the following species:

Aulophyllum fungites (Fleming), *Caninia cornucopiae* Michelin, *Dibunophyllum bipartitum* (M'Coy), *Diphyphyllum lateseptatum* (M'Coy), *Koninckophyllum echinatum?* (Thomson), *K. interruptum* Thomson and Nicholson, *Lonsdaleia laticlavia* S. Smith.

Brachythyris sp., *Dielasma sp.*, *Dictyoclostus pugilis* (Phillips), *Gigantoproductus latissimus* (J. Sowerby) group, *Pugnax pugnus* (Martin), *Spirifer sp.*

Known distribution. The Frosterley Band appears to be more restricted in distribution than the other faunal bands in the Great Limestone and is only well developed on the Alston Block. Northwards it does not appear to extend far beyond the Stubblick fault

line, the northern boundary of the block, though scattered simple corals do occur at about the correct horizon in some areas to the north, e.g. the Chollerford area, Northumberland. The band is particularly well developed in Weardale and Teesdale and is present on the Pennine escarpment. To the south of the Alston Block it has been recorded by Reading (1957) in the Cotherstone Syncline, and Wells (1958) at the north-east corner of the Askrigg Block, while Mr. Selwyn Turner has shown the writer a probable thin representative of the band in the upper Eden Valley south of Kirkby Stephen, Westmorland.

SYSTEMATIC PALAEONTOLOGY

GREEN ALGAE
Class CHLOROPHYCEAE
Order SIPHONALES
Family CODIACEAE
Genus CALCIFOLIUM Shvetzov and Birina 1935

Type species *Calcifolium okense* Shvetzov and Birina

In 1935 Shvetzov and Birina described *C. okense* from limestones of the Upper Okian Series, Upper Viséan (Lower Carboniferous), of the Moscow Basin but they did not give an exact generic diagnosis. Maslov (1956, p. 48) gives a generic diagnosis as follows:

> Thallus is composed of a cylindrical pipe-like siphon at first rather large and then branching dichotomously into pipes of constant diameter. Around the pipes a calcareous crust is deposited resulting in a calcareous skeleton of the following form. Attached to a cylindrical hollow-bodied calcareous stem are thin plates pierced by dichotomously branching canals which either fill the whole of the calcareous plate or are found only on one side of it. The plates branch to form other plates and are usually slightly curved. Organs of multiplication have not been observed.

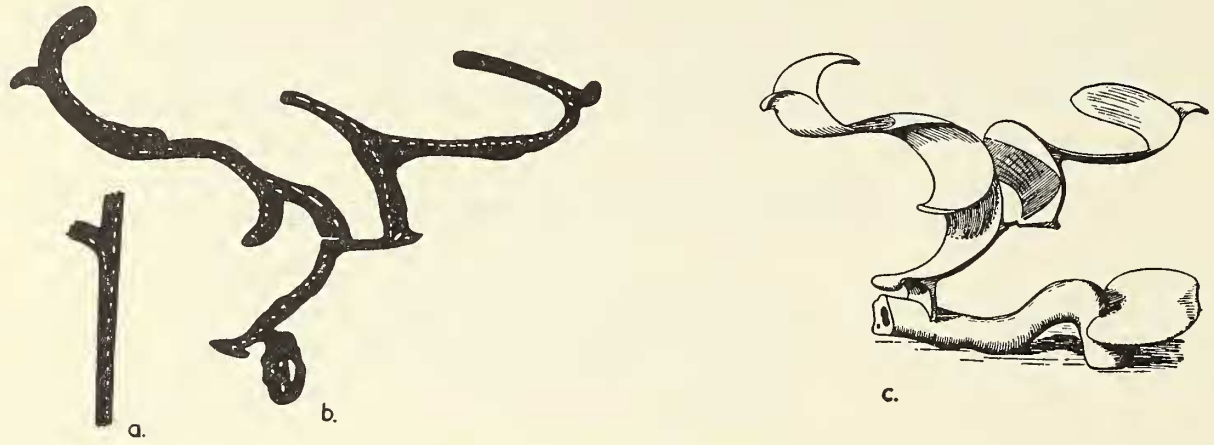
Remarks. Maslov (1956) restricted *Calcifolium okense* Shvetzov and Birina, retaining in *C. okense* only those forms with a single series of canals in the upper surface of the plates, and placing forms with two or three series of canals in a new species *C. punctatum* Maslov. In his description of *C. okense*, Maslov details the exact form of the thallus and on his pl. 10, fig. 5 and text-fig. 7*b* he figures the specimen of a complex branched plate which allowed the reconstruction of the whole of the skeleton; the text-figure (Maslov 1956, text-fig. 7*b*) is reproduced here (text-fig. 2*b*). Shvetzov and Birina (1935) did not commit themselves on the reconstruction of *Calcifolium* more than to suggest that the organism they describe must represent flat, broad leaves or blades having a network of canals nearer to one surface. Maslov (1956) devotes several paragraphs to the form and reconstruction of *Calcifolium* and shows that the organism is composed essentially of a hollow tubular central stem from which arise complex platy branches. The most probable reconstruction of *Calcifolium* according to Maslov is given on text-fig. 9*b* of his 1956 paper which is reproduced here (text-fig. 2*c*).

Calcifolium bruntonense sp. nov.

Plates 30 and 31; text-fig. 3*a-b*

Diagnosis. *Calcifolium* with large hollow branching tubular stem (siphon), initially 1 mm. in diameter, from which numerous complex smooth platy branches arise. Stem wall

between 100 and 200 μ thick and containing a series of irregular tubular canals which connect with canals in the lateral branches. Lateral branches are expanded distally, between 100 and 150 μ thick, and form wide plates which surround the central stem at the position of attachment. They contain a well-developed series of subcentrally placed



TEXT-FIG. 2. Transverse sections and reconstruction of *Calcifolium* (after Maslov 1956). (*a*) Transverse section of a forking branch of *C. okense*, ×50 (Maslov 1956, text-fig. 7*a*). (*b*) Drawing of a complex branched frond of *C. okense* which allowed the reconstruction of the whole skeleton, missing parts have been restored, ×50 (Maslov 1956, text-fig. 7*b*). (*c*) The most probable reconstruction of *Calcifolium* according to Maslov (1956, text-fig. 9*b*).

dichotomously branching parallel canals. The branches fork to form complex fronds of large and small curved branches.

Holotype. The specimen figured in Pl. 31, fig. 6; Brunton Band, Great Limestone, Brunton Bank Quarry, Chollerford, Northumberland (35/928570); basal Namurian, E_1 Zone (basal Upper Carboniferous). Geological Survey and Museum, London, reg. no. PF 619.

Paratypes. The specimens figured in Pl. 30, figs. 1–4 and Pl. 31, figs. 1–5, 7; same geological horizon as the holotype. Geological Survey and Museum, London, reg. nos. PF 617–618 and PF 620–622. Slides PF 617–618 from quarry 750 yards west 20° north of Grindon Hill House, Haydon Bridge, Northumberland (35/823684); slide PF 620 from Brunton Bank Quarry, Chollerford, Northumberland (35/928570); slide PF 621 from quarry 300 yards north-east of Beamwham Farm, Haydon Bridge, Northumberland (35/814684); slide PF 622 from quarry 100 yards east of Common House, Haltwhistle, Northumberland (35/718660).

Horizon. Abundant towards the centre and top of the Main Posts division of the Great Limestone, basal Namurian, E_1 Zone, Upper Limestone Group, Carboniferous Limestone Series of northern England. Locally it occurs in the underlying Four Fathom Limestone, uppermost Viséan, P_2 Zone, Middle Limestone Group, Carboniferous Limestone Series.

EXPLANATION OF PLATE 30

Figs. 1–4. *Calcifolium bruntonense* sp. nov., paratypes, approximately ×40. 1, Lateral branch in transverse section showing forking (top centre), fragment of lateral branch (right), wall of central stem showing internal canals (bottom left), PF 617. 2, Transverse and tangential section of a forking branch, PF 620. 3, Transverse and tangential sections of branches, PF 621. 4, Series of branches in longitudinal section showing forking at the distal extremity, PF 617.

Brunton Band, Great Limestone. PF 617 from Grindon Hill, Haydon Bridge; PF 620 from Brunton Bank Quarry, Chollerford; PF 621 from Beamwham Farm, Haydon Bridge.

JOHNSON, *Calcifolium bruntonense* sp. nov.

Dimensions. The following table shows the comparative dimensions of *C. bruntonense* sp. nov. and *C. okense* Shvetzov and Birina em. Maslov taken from Maslov (1956, p. 48):

	C. bruntonense	*C. okense*
Diameter of central stem	1 mm.	0·3 to 0·4 mm.
Thickness of walls of the central stem . .	100–200 μ	70–100 μ
Diameter of central stem wall canals . .	40 μ	. .
Length of individual branches, maximum . .	2 mm.	. .
Thickness of lateral branches	100–150 μ	70–100 μ
Diameter of canals in branches . . .	20–50 μ	16 μ
Angle of forking in canals	15°	10–25°
Distance between canals	15–20 μ	0–40 μ

Description. *C. bruntonense* is only visible in micro-sections of limestone and is normally seen as small narrow parallel-sided curved strips averaging 100–150 μ across (Pl. 31, figs. 5–7; text-fig. 3*a*). These fragments are transverse sections of broken lateral branches and show the internal system of canals as a row of small circular pores nearer to one margin. Sections of complete branches and the central stem are more rare. The central stem (Pl. 30, fig. 1; Pl. 31, fig. 1) is an irregularly curved hollow tube with walls up to 200 μ thick which contain a series of canals about 40 μ in diameter. These canals are irregularly spaced in the stem wall and appear to take a sinuous path. The central stem is initially 1 mm. thick but becomes narrower towards the distal extremity. The hollow central cavity of the stem may be divided by extensions of the wall into separate chambers but the evidence for this is at present inconclusive. The lateral branches are given off from the sides of the central stem (Pl. 30, fig. 1; Pl. 31, figs. 1, 6) and appear to surround it at the position of attachment. The branches are narrow near the base and expanded distally, usually curved and with slightly rounded margins. They are quite smooth and devoid of ornament and are almost uniform in thickness throughout. The primary branches given off from the central stem fork repeatedly to form complex fronds (Pl. 30, figs. 1–4; Pl. 31, figs. 2, 6). Forking seems to take place near the distal margin of the branches and is irregular. Within the lateral branches the canal system shows up conspicuously in both longitudinal and transverse sections. In longitudinal sections the canals are seen to be parallel and closely spaced at rather less than a canal width apart (Pl. 30, fig. 2; text-fig. 3*b*). The canals are of almost constant width, between 20 and 50 μ diameter, in individual branches but increase in number steadily by repeated forking. At the proximal extremity the canal system commences with a small number of canals which appear to unite at the base (Pl. 31, figs. 3, 4). The branching of the canals is dichotomous in each case and is frequently repeated again on both forks so formed though not necessarily at the same distance from the initial branching (text-fig. 3*b*). The canals increase in diameter near the position of branching and occasionally show slight swelling without branching taking place. The exact form of termination of the canals at the distal extremity is not known, though the canals are thought to lie nearer to the surface of the branch in this region.

Remarks. There is a striking similarity between specimens of *C. bruntonense* sp. nov. and *C. okense* Shvetzov and Birina em. Maslov which is immediately evident from Maslov's figures. In particular Maslov's text-figure (1956, text-fig. 7*b*) of a complex branch of